

# Ultrasonic Wedges for Testing Of Turbine Blade Roots

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**Abstract:** The integrity of turbine blade roots and attachments is fundamental to the power infrastructure. Therefore, it requires the adoption of appropriate wedges with an effective ultrasonic testing system. Turbine components have complicated geometry which ordinarily impedes proper coupling to the wedge. However, different configurations of the ultrasonic wedge have been developed to obviate this constraint. In this paper, the various types of ultrasonic wedge are reviewed vis-a-vis their conformability to the turbine blade root geometry. Also, the possible application of cylindrical multiple flat-faced wedges is discussed.

**Keywords:** Ultrasonic wedges, Testing, Turbine, Blade roots

## 1. Introduction

A turbine is a turbomachine with a rotor which has the turbine blades attached to it. Dynamic fluid or steam impinges on the blades, thereby causing the rotor to rotate simultaneously. Blade failures engender the disruption of power supply because the generating unit would automatically be rendered inactive. Steam turbine blade fracture occurs in low pressure (LP) turbine which is linked to

both the high pressure turbine and the generator. The examination of failed blades shows that crack originates at the trailing edge. This cracking is associated with a failure mechanism called high cycle fatigue (HCF) [1].

Another fracture mechanism in turbine blade root is stress corrosion cracking (SCC). When an alloy is subjected to stress in the presence of corrodants, the product is usually stress corrosion cracking. The turbine blades are often attacked by the corrodants, resulting in fracture [2].

The use of suitable wedges for ultrasonic testing is critical to the optimum refraction of sound waves into the test component. Several configurations ranging from straight, angled to contoured wedges have been utilized for ultrasonic inspection. Testing of components with planar faces is usually done with plain-faced wedges. However, for testing pipes and other radiused structures, contoured wedges are normally specified for enhanced sound refraction [3].

An ultrasonic wedge was developed in order to solve problem of lack of access to flaws within a threaded hole [4]. Within the same period, compound angle wedges were developed for curved specimens [5]. Also, an ultrasonic transducer with a flat or cylindrical lens was invented [6]. A research developed a technique for automatic wedge identification [7]. One study also produced contoured wedges for turbine blade roots [8] while another developed a novel wedge for pipe weldments [9]. Finally, a recent study developed conformable wedges with cylindrical surfaces for testing of turbine blade roots [10].

All of the above wedge models could be utilized in either traditional or phased array testing. However, geometric mismatch existed either between probe and wedge or between

the wedge and the test sample. The diagrams of the blade root and the scanning areas are shown as Fig. 1 below.

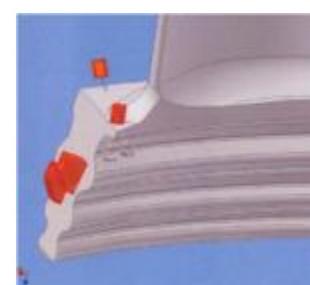
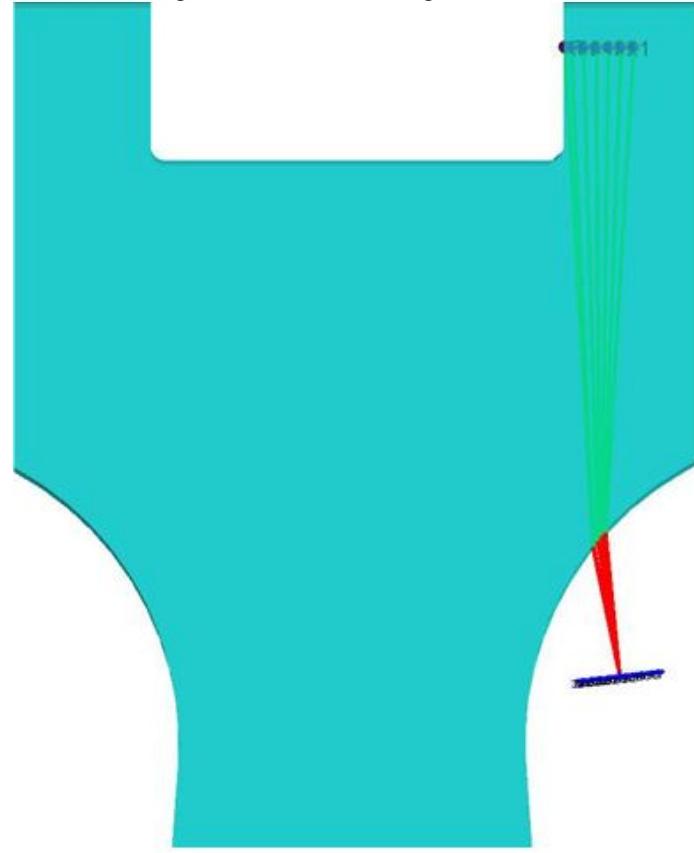


Fig. 1 Turbine blade roots

## 2. Developed Configurations of Ultrasonic Wedge

These include: the straight wedge, angle wedge, radiused or contoured wedge, and fully cylindrical wedge.

### 2.1 The Straight Wedge

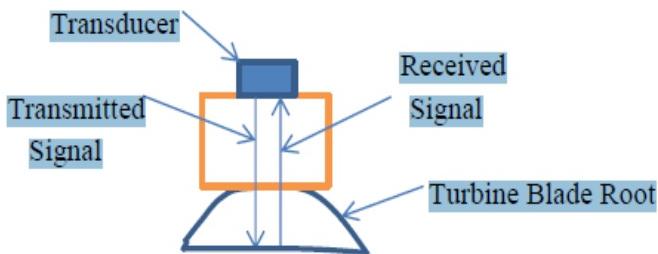


Fig 2.1 Straight Wedge/Specimen Assembly

In Fig 2.1, there is no full contact between the straight wedge and the turbine blade component. Secondly, refraction of sound wave is absent because the same transmitted longitudinal wave is received back by the probe.

## 2.2 The Angle Wedge

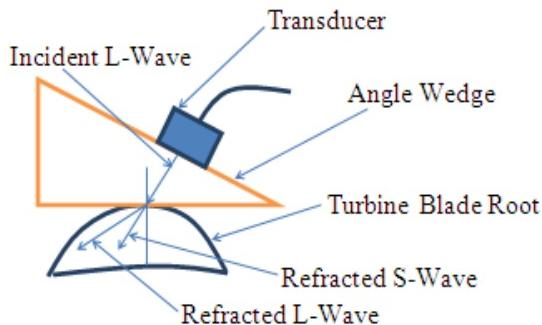


Fig 2.2 Angle Wedge/Specimen Assembly

In Fig 2.2, the angle wedge and the specimen slightly mate. However, there is sound refraction into the blade root because angle wedges enable the transmission of shear wave by mode conversion [3].

## 2.3 Radiused Angle Wedges

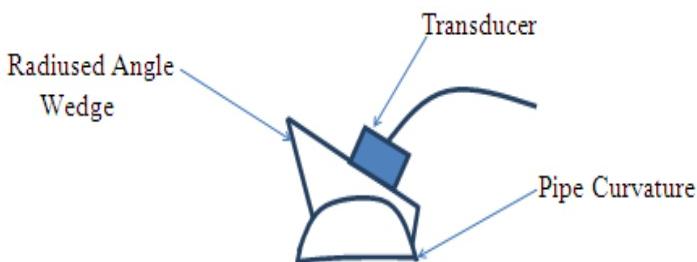


Fig 2.3 Radiused Angle Wedge/ Specimen Assembly

Radiused or contoured wedges are used to test curved specimen so that sound waves can be effectively coupled into it. The more the curvature, the less the contact between the test piece and the wedge. This phenomenon will reduce the quantity of wave energy that is refracted and also increase noise reflections [3].

## 2.4 Fully Cylindrical Wedge

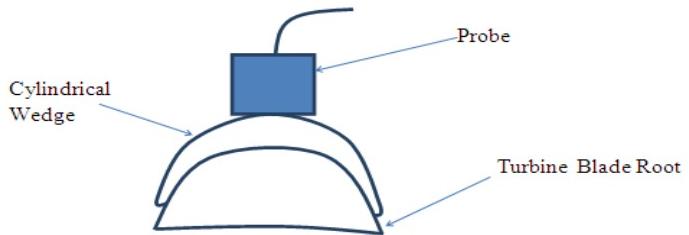


Fig 2.4 Cylindrical Wedge/Specimen Assembly

In Fig 2.4, proper coupling of the wedge to the blade exists but there is an obvious mismatch between the probe and the wedge. Consequently, the amount of sound refraction into the specimen will be less. Moreover, the pin holes where cracks initiate first in the turbine blade roots will go undetected.

## 3. The Cylindrical Multiple Flat-faced Wedge Model

In view of the state of the art in this study, the cylindrical multiple flat-faced wedge model is hereby suggested in order to resolve problems of geometric mismatch.

Figs 3.1 & 3.2 below show the schematic solidworks models of the proposed wedge.

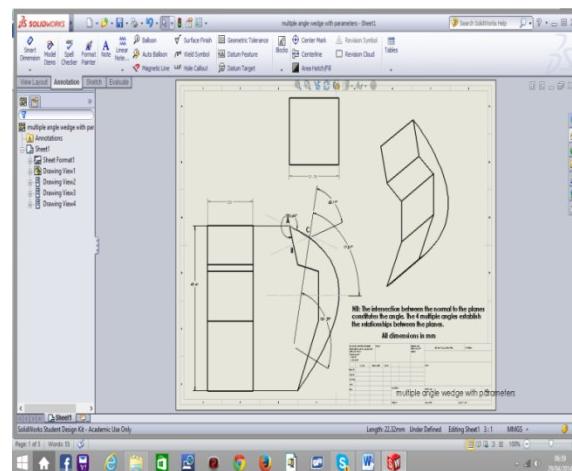


Fig 3.1. The cylindrical multiple flat-faced wedge model

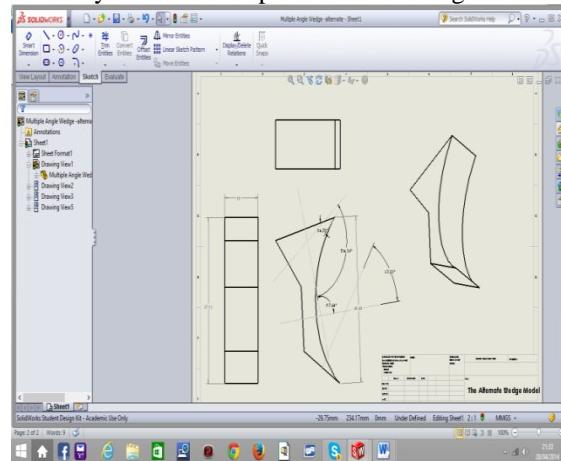


Fig 3.2. The alternate wedge model

The cylindrical multiple flat-faced wedge model shown as Fig 3.1, has a convex cylindrical geometry that can mate with the concave surface of the blade root. The wedge also has an opposite scanning side which is made up of planar faces at different wedge angles. Since the blade root has both concave and convex geometry [11], an alternate cylindrical multiple flat-faced wedge (i.e. Fig 3.2) would also be made to test the convex part of the roots. The optimum coupling of the proposed wedge model to the turbine blade root model is shown as Fig 3.3 below.

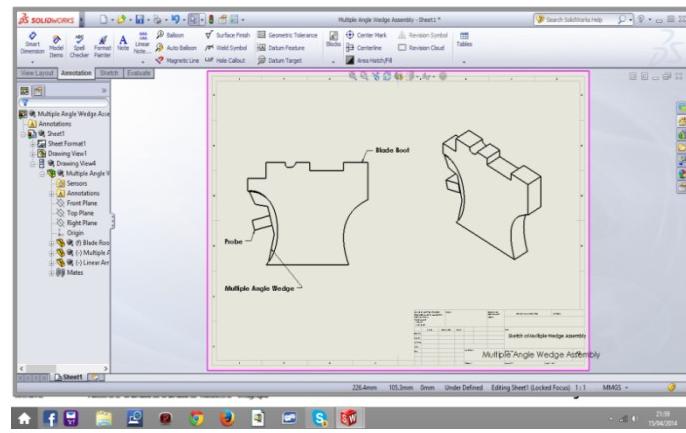


Fig 3.3 The Wedge Model Coupled to the Turbine Blade Root

This proposed wedge model, when developed, would perform optimally either with an individual or phased array testing technique. Also, a comprehensive simulation of the wedge/blade root models should be carried out in PZFlex software to establish the appropriate focal laws.

#### 4. Conclusions

The effectiveness of ultrasonic wedges cannot be optimized if there is a geometric mismatch at the interfaces. Since previous and existing configurations have various degrees of mismatch,

several flaws definitely would not be identified by the testing instruments. This error could lead to turbine failure with its attendant consequences.

Finally, the development of cylindrical multiple flat-faced wedge model will greatly enhance the performance of ultrasonic wedges for the testing of turbine blade roots.

#### References

- i. Zdzislaw M, Rafael G-I, Jorge A-R, Norberto P-R (2008), 'Steam turbine blade failure analysis', *ScienceDirect*, vol 15, Issues 1-2, pp129-141.
- ii. 'Failure Analysis of Turbine Blades', Available at <http://www.metassoc.com/site/services/failure-analysis/failure-analysis-of-turbine-blades/>
- iii. 'An Introduction to Angle Beam Assemblies', Available at <http://www.olympus-ims.com/en/applications/angle-beam-transducers/>
- iv. Donald A.G (1982), 'Wedges for Ultrasonic Inspection' US Patent No. 4,359,905.
- v. David O.H (1982), 'Compound Angle Wedges for Coupling Ultrasound into Curved Surface Object', US Patent No. 4,353,258.
- vi. Henry H, Jr (1982), 'Multiple wedge element lens for an ultrasonic inspection transducer', US Patent No. 4319490A.
- vii. Kirk M, Jason H (2010), 'Method and System for automatic wedge Identification for an ultrasonic Inspection System' US Patent Claim No: 20100250151.
- viii. Michael F, Hans R, Michael S (2003), 'Blade Root/Blade Attachment Inspection by Advanced UT and Phased Array Technique', Paper presented at 6<sup>th</sup> International Charles Parsons Turbine Conference.
- ix. Fredrik H, Malcolm A.S, Mike J.T (2011), 'Development of Inspection techniques for an Automated Non-Destructive Evaluation (NDE) approach for testing welded joints in plastic (PE) Pipes', *BINDT Journal*.
- x. Charlesworth C (2011), 'Ultrasonic Phased array testing in the power generation industry; Novel wedge development for the inspection of steam turbine blade roots', *PhD Thesis, University of Warwick, England*.
- xi. Ferleger J, Correl D.R (2000), *Turbine Blade Geometry (online)*. Available at <http://www.freepatentsonline.com/EP0654585.html>